POTENTIALS

RFCS AM PROJECT

BEST PRACTICE GUIDELINES

Synergistic potentials of end-of-life coal mines and coal-fired power plants: update and re-adoption of territorial just transition plans

www.potentialsproject.eu

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The study was reviewed and edited by the Coordinator of the project, Prof Dr Eng Alicja Krzemień, from the Central Mining Institute – National Research Institute in Katowice, Poland, and Prof Dr Eng Pedro Riesgo Fernández, from the School of Mining, Energy and Materials Engineering of Oviedo, Spain.

WHO SHOULD READ THESE BEST PRACTICE GUIDELINES, AND HOW SHOULD THEY BE READ

These best practice guidelines are primarily addressed to policymakers at the European level, competent authorities responsible for the development of territorial just transition plans in Europe, authorities of coal regions in transition and managers of end-of-life coal mines and coal-fired power plants who have to decide on future developments and who consequently have to consider in the pre-closure phase the aspects needed to be arranged before closure.

The timeline for ceasing or scaling down activities may vary according to the specific conditions of the area. However, according to our experience, five years should be the appropriate timeframe to develop the pre-closure phase. As it is not possible in many cases to foresee the closure of the mine with such anticipation, a two-year period should be the minimum requirement to undergo this phase.

Other stakeholders, such as environmental institutions, NGOs, private investors and citizens, may find these guidelines interesting to understand the problems and the advantages of the different alternatives that may be pursued.

These guidelines are easy to read. Nevertheless, stakeholders not interested in the process may go directly after the Introduction through Chapter Five and the Conclusions. In every chapter, it is always possible to obtain more detailed information by clicking on the hyperlink.

Executive summary

The POTENTIALS project focuses on the unique aspects of coupled end-of-life coal mine sites, coal-fired power plants, and closely related neighbouring industries, using their synergistic opportunities to stimulate new economic activities and jobs in Coal Regions in Transition, guaranteeing a sustainable and combined use of assets and resources otherwise overlooked in the high-velocity environments of phasing out processes.

Trying to ensure that these alternatives also contribute to the objectives of the European Green Deal, the repurposing was directed at new or improved technologies and business models that rely on renewable energy or scale energy storage or contribute to the circular economy.

To achieve this goal, POTENTIALS uses one of the most widely employed methodologies to accomplish prospective analysis: the scenario method proposed by Godet (http://en.laprospective.fr/dyn/anglais/articles/art_of_scenarios.pdf), a creative and structured process to undergo strategic foresight and a differentiating factor in decision-making.

First, a structural analysis was developed to select the technical variables that better identify this complex system. Second, a morphological analysis allowed the construction of the scenario space. Third, a multicriteria assessment was developed to achieve this goal.

Finally, result indicators were selected to analyse the alternative options derived from the justification approach, considering the targets set by the European Green Deal and related taxonomy and the regional policy indicators for the Just Transition Fund.

Based on the achieved results, POTENTIALS developed a roadmap for updating territorial just transition plans, which are at the centre of the Just Transition Mechanism and a reference for all its pillars, setting out the social, economic, and environmental challenges and detailing the needs for economic diversification, reskilling and environmental rehabilitation as appropriate.

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1 Introduction

POTENTIALS project focuses on repurposing end-of-life coal mine sites, coal-fired power plants, and closely related neighbouring industries by deploying emerging renewable energy and circular economy technologies to help develop a renewable-based energy sector, promote sustainable local economic growth, and maximise the number of new and quality jobs.

It is perfectly aligned with the European Green Deal policies regarding the supply of clean, affordable, and secure energy, as well as mobilising the industry for a clean and circular economy. Policymakers support the acceleration of the energy transition by deploying renewable energy, encouraging policies that establish the appropriate environment for the extensive penetration of renewables, and balancing the national urban structure to strengthen self-sustained urban development and guarantee a sustainable future.

Repurposing these sites utilises elements of the mine industry infrastructure (housing and roads) and landscape aspects (such as mine voids and waste heaps) for alternative post-closure activities. These activities may assist in transitioning the local economy and mitigating the loss of activity by establishing new forms of attachment to the region.

To achieve this goal and to justify the business model choice, a multicriteria assessment was developed based on previously assessed relevant scenarios and micro-scenarios. A scenario is considered a standalone technology or a combination of technologies that provides a complete solution for repurposing these areas to build a specific business model. Furthermore, a micro-scenario is a complementary solution that should be combined with other scenarios or micro-scenarios to create a comprehensive business model.

The scenarios and micro-scenarios were evaluated against the European Green Deal policies using assessment criteria resulting from interactions between researchers, industry experts, and stakeholders in the planning process. In most cases, empirical analyses of environmental innovations relied on surveys that allowed for the inclusion of many explanatory variables, such as different policy instruments or the influence of pressure groups. These assessment criteria were selected to grasp priorities about their contribution to the climate-neutral economy transition, their lead on reductions in greenhouse gas emissions going below the relevant benchmarks, and their contribution to generating jobs and economic growth and embodying them in the subsequent processes.

However, to have a global vision of the problem, additional technical variables, which were not explicitly considered under the European Green Deal policies and are needed to assess the technological alternatives properly, were also analysed within the assessment approach.

To select the specific scenario to be developed, it was taken into account the following variables that characterise these end-of-life coal environments:

- the technology readiness level (TRL) that allows for more effective assessment and better communication on the maturity of new technologies;
- the European taxonomy, a classification system establishing a list of environmentally sustainable economic activities, significant in helping the EU scale up sustainable investment and implement the European Green Deal;
- the synergistic potential, guaranteeing a sustainable and combined use of assets otherwise overlooked in the high-velocity environments of phasing-out processes;
- the circular economy, which keeps materials, products, and services in circulation for as long as possible;
- and sector coupling, which involves the increased integration of energy end-use and supply sectors, improving the efficiency and flexibility of the energy system, as well as its reliability and adequacy, while reducing the costs of decarbonisation.

In the first stage, technical variables characterising end-of-life coal mine environments were determined, where they were related to implementing business models relying on energy based on renewable resources that contribute to the circular economy or energy storage in closed coal mines. The technical variables were evaluated using the structural analysis method. The set of technical variables for the structural analysis was obtained via consensus, applying the Delphi method.

In the second stage, a specific analysis was developed to identify technical variables for scenario development, mainly via a combination of results from the structural analysis.

In the third stage, the identification of potential scenarios that could be implanted as business models in end-of-life coal mines was performed using morphological analysis.

The obtained scenarios were then evaluated using a multicriteria analysis. In the last stage, justifying and assessing the business model's choice by specifying outputs and result indicators was done.

The results show that eco-industrial parks with virtual power plants represent the most appropriate business model choice, according to the scoring given to the different aspects. A hydrogen production plant may complement them, provided that specific economic subventions are obtained to achieve balanced financial results.

Finally, using the MoSCow technique, the POTENTIALS project also provides clear advice on which business models should be prioritised during the update of activities within the territorial just transition plans and accompanying actions to allocate the budget accordingly.

2 Structural analysis: technical variables assessment

2.1. Defining technical variables

Before proceeding with the structural analysis, the variables considered relevant for the proposal were identified, analysed, and reduced according to their representability. Variables, internal and external, refer to the characterising of both technical (e.g. water temperature, flying ashes characterisation, waste heaps soil characterisation, etc.) and evaluation criteria (e.g. cost, competitiveness, etc.) related to renewable energy technologies, scale energy storage, assets, resources and circular economy contributions.

An unsorted list of variables is the output of this step (Fig. 2.1). Of course, not all the sources agreed on the importance of the variables or even in identifying what aspects should be formalised as a variable or which should not. A detailed explanation of the variables was provided, allowing a better perception of the relations between these variables further in the analysis.

Number	Key Variables	Definition preparation Interest of (volunteers)	Verified by	Short definition (up to 200 characters w/o spaces) FOR EXPERTS in MICMAC analysis
1	Depth of mine	GIG	UNIOVI	The variable determines the maximum depth of the mine - the depth at which the deepest exploitation level is located or where the deepest workings/goafs are located and that can be adapted to produce green energy.
2	Ground movement	GIG	UNIOVI	The variable determines the possible tectonic movement of rock mass influencing underground workings/reservoirs/shafts and infrastructure on the surface (after the end-of-life of the coal mine with or without flooding of the mine).
3	Geological singularities of the mine	GIG	UNIOVI	The variable referes to the existence of singular geological structures in the mine: impermeable strata, absence of faults, etc. (with no geological disturbance)
4	Methane surface emissions (AMM)	HUNOSA	GIG	The variable determines the concentration, flow and an estimation of future emissions of Abandoned Mine Methane (AMM).

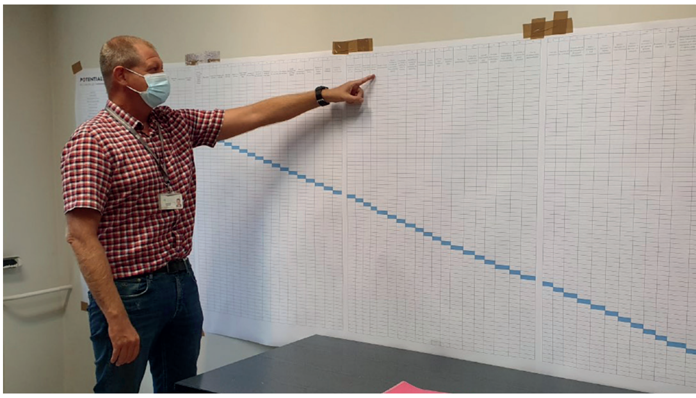
Fig. 2.1 Unsorted list of variables

Lessons learnt were that each partner initially came with their view, understanding, approach, and methodology based on structured expert judgment and multicriteria analysis. Based on improving information discussion among the project partners (internal stakeholders), adopting a framework to facilitate a common understanding of the different options and opinions became evident. Pre-defining a common methodology/ framework can significantly reduce the time to reach a consensus and free up resources for more technical details.

Unsorted list of variables

2.2. Describing the relationships between technical variables

Next, different experts stated each variable's influence over the rest of the system variables. The groups of experts provided a n x n integer matrix that states these influences based on their knowledge and expertise. The matrix entries are generally qualitative, adjusting the intensities of the relations among the variables, as in a systemic vision, a variable does not exist other than as part of the relational web with the other variables. This phase helps to put for n variables n x (n-1) questions (4,692 for 69 variables), employing direct brainstorming sessions or panel sessions. It was developed with a two-round Delphi-based study. This procedure allows not only avoiding errors but also correcting inconsistencies within the first Delphi round and redefining the variables and, thus, refining the system's analysis.



After the information collected and the two-round Delphi-based study, a Matrix of Direct Influence (Fig. 2.2) describing the relation of direct influences between the variables defining the system was then developed.

Matrix of Direct Influence

Lessons learnt were that the discrepancies between the responses in the Matrix required a second round of Delphi study. The revision of the results showed that, in some cases, experts could evaluate the relation between two variables. However, without proper identification of the direction of influence, i.e., the Influence of *Companies manufacturers of goods and/or suppliers of services* on *Access/proximity to gas pipeline network connections* does not exist. The opposite was identified: *Access/proximity to gas pipeline network connections* may affect *Companies manufacturers of goods and/or suppliers of services*. The second round of the Delphi study benefited from the knowledge and experience of external experts, who positively influenced the final results.

POTENTIALS RFCS AM PROJECT		1	2	3	4	5	6	7
		Depth of mine	Ground movement	Geological singularities of the mine	Methane surface emissions (AMM)	Methane resources (CBM)	Coal spontaneous ignition	Coal processing plant capacity
1	Depth of mine		3	3	3	3	1	0
2	Ground movement	0		0	1	0	1	0
3	Geological singularities of the mine	3	3		2	2	2	0
4	Methane surface emissions (AMM)	1	0	0		0	0	0
5	Methane resources (CBM)	0	0	0	3		0	0
6	Coal spontaneous ignition	0	0	0	1	0		0
7	Coal processing plant capacity	1	0	0	0	0	0	

Fig. 2.2 *Matrix of Direct Influences*

2.3. Identifying the key technical variables

Structural analyses of mutual influences and relationships between variables were carried out. The MICMAC software, developed by the Institut d'Innovation Informatique pour l'Entreprise 3IE, was used to analyse direct, indirect and potential influences. The result of the analysis was a structured database of grouped variables.

Two methods were applied: the direct method, which estimates the overall direct influence and direct dependence of a variable in the system directly from the Matrix, and the indirect method, which estimates the overall influence and dependence of a variable through other system variables. The comparison of the results (direct and indirect classification) confirms the importance of specific variables and reveals certain variables that, because of their indirect actions, play a dominant role (and which the direct classification did not allow revealing). Therefore, the comparison of the hierarchy of the variables in the various classifications is rich in information, providing the key technical variables of the system (Fig. 2.3).

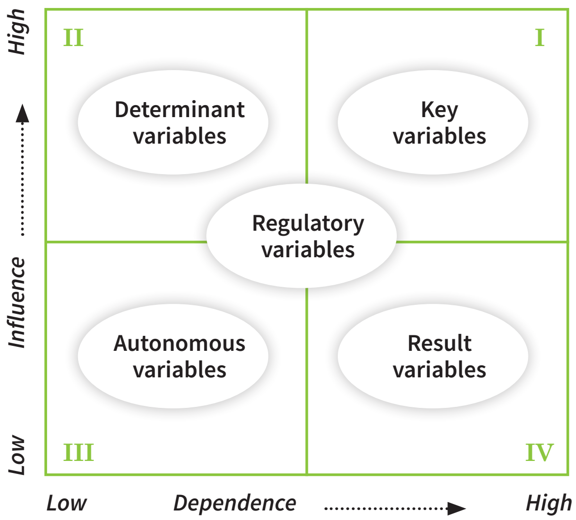


Fig. 2.3 Grouping of technical variables by dependence and influence

Two were the main lessons learnt. In the first place, the main problem when performing structural analyses was the wide variety and range of variables. The number and diversity of variables, on the one hand, accounted for the high content value of the Matrix, and on the other hand, posed a challenge for the appropriate selection of parameters for the analyses.

The structural analysis performed for all variables indicated that the key variables for the whole system are only those from the "Power plant" group. This was mainly because the variables in the "Mining" group referred to both the underground and surface parts of the mine, which meant that most did not show any influence/dependence on the others. In contrast, there were more influences/dependencies between the variables in the "Power plant" group, which consequently caused the variables in this group to 'dominate' the results of the analyses. Therefore, it was decided, in addition to the system-wide analysis, to conduct analyses for three groups of variables: "Power plant", "Surface mining", and "Underground mining" separately. The results obtained from these analyses allowed the identification of key variables in the above areas, which would not have been possible with a holistic analysis.

In the second place, it was observed that variables with similar characteristics occupied places close to each other in the system in three cases, which allowed them to be combined into one variable without any negative impact on the system.

Key technical variables

3 Morphological analysis: Scenario assessment

3.1. Constructing exploratory scenarios

Morphological analysis can help fire the imagination, help identify new products or previously unknown procedures, and sweep the field of possible scenarios. The issue of choosing key variables and their order, plus the relevant alternatives, is a determining one for the pertinence, coherence, plausibility, and transparency of the scenarios.

The selected scenarios were assessed using morphological analysis as the best method to explore the possible recombination of elements that make up the structural analysis. This method is mainly used for constructing scenarios but is equally suitable for forecasting technology development and creating potentially new products or services. The MORPHOL tool, also developed by the Institut d'Innovation Informatique pour l'Entreprise 3IE, was used for this purpose.

Starting from the structural analysis, it was necessary to include a selection of the key technical variables used for scenario development with morphological analysis (Tab. 3.1). It is interesting not to select many variables so that the field of possibilities or "morphological space" does not become huge and impossible to handle.

Tab. 3.1 List of technical variables for scenario development

Technical variables	Description
Character of the local area/ proximity to industry	This technical variable describes the characteristics of the surrounding areas: industrial and post-industrial, urban, suburban, rural, and agricultural. The type of local area determines the type and amount of connectivity to infrastructure facilities.
Available space for new technologies/projects	This technical variable refers to the available space available to install new technologies (it does not include waste storage areas). This space includes all areas provided by the surroundings of a coal power plant or coal mine.
Available infrastructures for new technologies	This technical variable includes the type of infrastructure that can facilitate the power plant/mine adaptation. It can be an internal infrastructure, such as water demineralisation facilities, or external infrastructure, such as a water purification station or a water pumping station.
Concessions, contracts and other regulations	This technical variable refers to obligations such as providing a thermal energy supply after the decommissioning or those arising from legal regulations, which may determine the future destinations of the mine.
Land use restrictions	This technical variable considers land use restrictions (other than waste heaps), mainly related to land use plans approved by local authorities, which may condition specific industrial, commercial, or residential centres.
Physical characteristics of waste heaps	This technical variable refers to the waste heap's physical characteristics—geotechnical stability, angle of natural response, geomorphic shape, and waste heap height and area.
Waste heap development constraints	This technical variable refers to waste heap development constraints (gas and fire hazards and reclamation status).
Material type deposited on the waste heaps	This technical variable describes the specific characteristics of the materials deposited on the heaps, considering whether they are separated into mining waste and coal preparation waste or mixed.
Flooding status of the mine	This technical variable describes the flooding status of a closed mine. It is related to the depth to which it was flooded and the size of the flooded underground area/excavations.
Pumped water chemistry/ quality	This technical variable determines the quality and chemistry of pumped mining water (salt, hazardous substances).

First, technical variables for scenario development from the structural analysis were identified. Second, each technical variable's development alternatives were selected and justified for a working horizon. Third, morphological analysis was used to evaluate the possible recombination of the elements comprised in the investigated system.

Apart from the morphological analysis, some scenarios were obtained via ideas from the consultation process and via brainstorming among the partners in order not to leave specific combinations of variables that, due to time constraints, did not appear during the analysis.

The result of this work was the "scenario space", characterised by all the feasible combinations of system components. The scenarios obtained were arranged and transformed into a list of relevant business models after eliminating some feasible scenarios to be developed without achieving any essential synergies from coupled end-of-life coal mine sites, coal-fired power plants, and closely related neighbouring industries.

Dominios	Variables	Hipótesis				
		H1	H2	H3	H4	H5
POTENTIALS	Area characteristics	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Infrastructures	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concession / obliga.	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Heaps characteristic	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Heaps constaints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Heaps material	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Water quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

***Fig. 3.1** Technical variables and their alternatives*

Lessons learnt in this process were that identifying the final variables was somewhat complicated, as sometimes several variables could be combined into one, and some of them represented development hypotheses for a specific working horizon of the variable. In other cases, variables were directly related to other variables and eliminated from the analysis. Also, several variables did not condition the development hypothesis for a given working horizon, so the analysis did not consider these variables. In some cases, combining several variables into one variable was possible.

After this process, the final number of variables selected from the three groups for the morphological analysis was only ten (Fig 3.1). However, combining the different hypotheses for each variable allows a total of 100,000 possible scenarios to be calculated. Thus, the scenario space was large enough to allow for a profound analysis of the system.

Finally, the scenarios obtained from the morphological analysis were arranged and transformed into a list of relevant scenarios and micro-scenarios (Tab. 3.2 and Tab.3.3).

Tab. 3.2 List of relevant scenarios

Nº	Scenarios	Description
1	Virtual	Scenario "Virtual power plant"
2	Hydrogen	Scenario "Green hydrogen plant"
3	Ecopark	Scenario "Eco-industrial park"
4	Tourism	Scenario "Cultural heritage and sports/recreation areas using green energy"
5	FloatingPV	Scenario "Floating PV panels at flooded open-pit coal mine"
6	Pumping	Scenario "Pumped hydroelectric storage (PHS) at former open-pit coal mines"
7	Fisheries	Scenario "Fisheries in flooded open-pit coal mines"
8	CCGT	Scenario "Combined-cycle gas turbine (CCGT) powered by natural gas"
9	Minegas	Scenario "Mine gas utilisation for gas-powered CHP power units"
10	Nuclear	Scenario "Small modular reactors (SMRs)"
11	Biofuels	Scenario "Biofuel combustion or production"
12	Molten salt	Scenario "Molten salt plant"
13	Agrophotovoltaics	Scenario "Agrophotovoltaics (APV) at former open-pit coal mine areas"

Tab. 3.3 List of relevant micro-scenarios

Nº	Micro-scenarios	Description
1	Batteries	Micro-scenario "Ancillary services provided by batteries"
2	Waste heaps	Micro-scenario "Circular mining technologies based on material recovery"
3	Methane	Micro-scenario" Usage of methane from degasification units in closed coal mines"
4	Water	Micro-scenario "Circular mining technologies for pumped water material recovery"
5	Forest	Micro-scenario "Forest restoration at former open-pit coal mines"
6	Information	Micro-scenario "Large-scale IT infrastructure"
7	Geothermal	Micro-scenario "Geothermal energy"
8	Gravitricity	Micro-scenario "Gravitricity"
9	Dense fluids	Micro-scenario" Dense fluids"
10	Hydropumping	Micro-scenario "Underground hydro-pumping"

Exploratory scenarios

3.2. Evaluating scenario options by Multicriteria assessment

Scenario and micro-scenario (complementary solutions that should be combined with other scenarios or micro-scenarios to create a comprehensive business model) options were evaluated using multicriteria assessment and the MULTIPOL tool (an acronym for MULTIcriteria and POLicy), also developed by the Institut d'Innovation Informatique pour l'Entreprise 3IE.

MULTIPOL is one of the most straightforward existing multicriteria applications but is not the least useful. It is based on evaluating actions using a weighted average, similar to evaluating students in a class calculated according to coefficients per subject. Classic multicriteria approaches are used in MULTIPOL: census possible scenarios, analyse consequences, elaborate on criteria, evaluate scenarios, define policies, and sort scenarios. Hence, every scenario is evaluated, considering each criterion with a simple scale. Evaluation is possible via either questionnaires or meetings with experts, where a consensus is necessary.

Furthermore, scenario evaluation is not uniform in that different contexts related to the objective are also considered. One of these contexts is a policy: a set of weights tuned to the criteria. These weights represent different value systems for decision-makers, diverse strategies, multiple scenarios, and assessments, including possible changes in the time horizon. Experts assign an appropriate weight for each policy adopted based on the assumed criteria. Policies from the European Green Deal have been selected, assuming that climate change coupled with ongoing environmental degradation are existential threats to Europe and the world, and that should be addressed in terms of scenarios and micro-scenarios (Tab 3.4).

Tab. 3.4 List of European Green Deal policies

Nº	Policies	Description
1	Climate	Policy "No net emissions of greenhouse gases by 2050"
2	Growth	Policy "Economic growth decoupled from resource use"
3	People	Policy "No person and no place left behind"

For each policy, an average score is assigned to the scenarios, and a table of classification profiles is created compared to the policy scenarios. An assessment of the risks associated with uncertainty or incompatible alternatives is obtained using a scenario classification map based on the mean values and standard deviations of the results obtained for each policy.

Then, evaluation criteria emanating from the goal and objectives of the study were defined as an outcome of interaction among researchers, external experts, and stakeholders in a participatory planning process, aiming to grasp priorities and embody them in the subsequent processes (Tab. 3.5). The evaluation of scenarios and micro-scenarios related to policies was developed using these inputs.

Tab. 3.5 List of assessment criteria

Nº	Evaluation criteria	Description
1	Security	Criteria "Energy security"
2	Greening	Criteria "Renewable resources"
3	Cost	Criteria "Low investment barriers"
4	Benefits	Criteria "Benefits"
5	Development	Criteria "Regional development"
6	Environment	Criteria "Environment"
7	Employment	Criteria "Job creation"

Once criteria and policies were selected, evaluating scenarios/micro-scenarios and policies related to criteria was performed. These evaluations were also developed with the participation of project partners and external experts from the countries involved in the project. The result was a rank of scenarios and micro-scenarios by policy (Tab. 3.6 and Tab. 3.7) and a closeness map between scenarios and micro-scenarios and policies that can be used to determine which actions are to be chosen whilst considering policies and convergences between policies and given scenarios. They provide a good starting point for designing specific business models, which often will be combinations of scenarios and micro-scenarios.

Tab. 3.6 *Result of evaluation of scenarios related to policies*

SCENARIOS	POLICIES			Mean	Standard deviation
	Climate	Growth	People		
Virtual power plant	13.3	9.4	7.4	10	2.5
Green hydrogen plant	16.4	10.5	10.9	12.6	2.7
Eco-industrial park	12.5	12.9	15.9	13.8	1.5
Cultural heritage and sports/recreations	10	8	9.2	9.1	0.8
Floating PV panels at flooded open pits	12.5	9.6	8.5	10.2	1.7
Pumped hydroelectric storage	17.2	11.5	9.6	12.8	3.2
Fisheries in flooded open-pit coal mines	5.6	7.8	8.1	7.2	1.1
CCGT	10.8	11	9.7	10.5	0.6
Mine gas utilisation in CHP units	6.4	6.4	5.3	6	0.5
Small modular reactors (SMRs)	14.2	11.7	15.1	13.7	1.4
Biofuel combustion or production	15	13.2	12.4	13.5	1.1
Molten salt plant	18.1	13.8	10.9	14.2	3
Agrophotovoltaics	15.3	11.4	10.1	12.3	2.2

Coloured figures indicate the three highest values achieved within each policy. Bold scenarios correspond to those with at least one coloured figure.

Tab. 3.7 Result of evaluation of micro-scenarios related to policies

MICRO-SCENARIOS	POLICIES			Mean	Standard deviation
	Climate	Growth	People		
Ancillary services with batteries	13.8	10.8	5.8	10.1	3.3
Waste heap material recovery	5.8	6.3	7.1	6.4	0.5
Usage of methane	8.5	7.8	7.8	8	0.3
Pumped water material recovery	7.5	6.2	6.4	6.7	0.6
Forest restoration at open pits	7.5	7.2	7.2	7.3	0.1
Large-scale IT infrastructure	4	6	2.8	4.2	1.3
Geothermal energy	19.6	14.5	12.4	15.5	3
Gravitricity	12.2	8	7.6	9.2	2.1
Dense fluids	18.5	10.8	8.8	12.7	2.8
Underground hydro-pumping	18.2	10.5	9.3	12.7	3.9

Coloured figures indicate the three highest values achieved within each policy. Bold scenarios correspond to those with at least one coloured figure.

Lessons learnt in this process were that the highest rank was given to the "Molten salt plant" scenario concerning the climate and growth policies. Concerning the People policy, it was given to "Eco-industrial park". The analysis of the sensitivity map shows that the highest mean for the three policies, with the lowest standard deviation, is characterised by the following scenarios: "Eco-industrial park", "Small modular reactors", and "Biofuels processing energy plant". Closeness map analysis between scenarios and policies shows that "Pumped hydroelectric storage at former open-pit coal mines" is the closest to the Climate policy, while "Mine gas utilisation for gas-powered CHP power units" is the closest to the Growth policy and "Eco-industrial park" to the People policy.

In evaluating micro-scenarios concerning the policies, the highest rank was "Geothermal energy" concerning the Climate, Growth and People policies. None of the micro-scenarios has a high mean and a low standard deviation relative to the three policies. The analysis of the sensitivity map shows that the highest mean for the three policies, with the higher standard deviation, is characterised by the following micro-scenarios: "Geothermal energy", "Underground hydro-pumping", and "Dense fluids". Closeness map analysis between micro-scenarios and policies shows that "Dense fluids" is the closest to the Climate policy, "Geothermal energy" is the closest to the Growth policy, and "Forest restoration at former open-pit coal mines" is the closest to People policy.

Scenarios classification map

4 Update and re-adoption of territorial just transition plans

4.1. Business Model Choice

The justification approach was initially based on evaluating scenarios/micro-scenarios related to Green Deal policies. However, to complement this evaluation other aspects were considered: (1) Technical criteria or relevant variables for scenario development; (2) Technology Readiness Level (TRL) to assess the maturity of new technologies; (3) European taxonomy to establish which economic activities are environmentally sustainable; (4) Synergistic potential, to take advantage of the joint potential of end-of-life mine sites and coal-fired power plants (and related infrastructure), along with closely related neighbouring industries; (5) Circular economy, to enable resources to maintain their highest value for as long as possible; and (6) Sector coupling, to improve the efficiency and flexibility of energy systems and their reliability and adequacy by integrating energy end-use and supply sectors (Fig. 4.1).

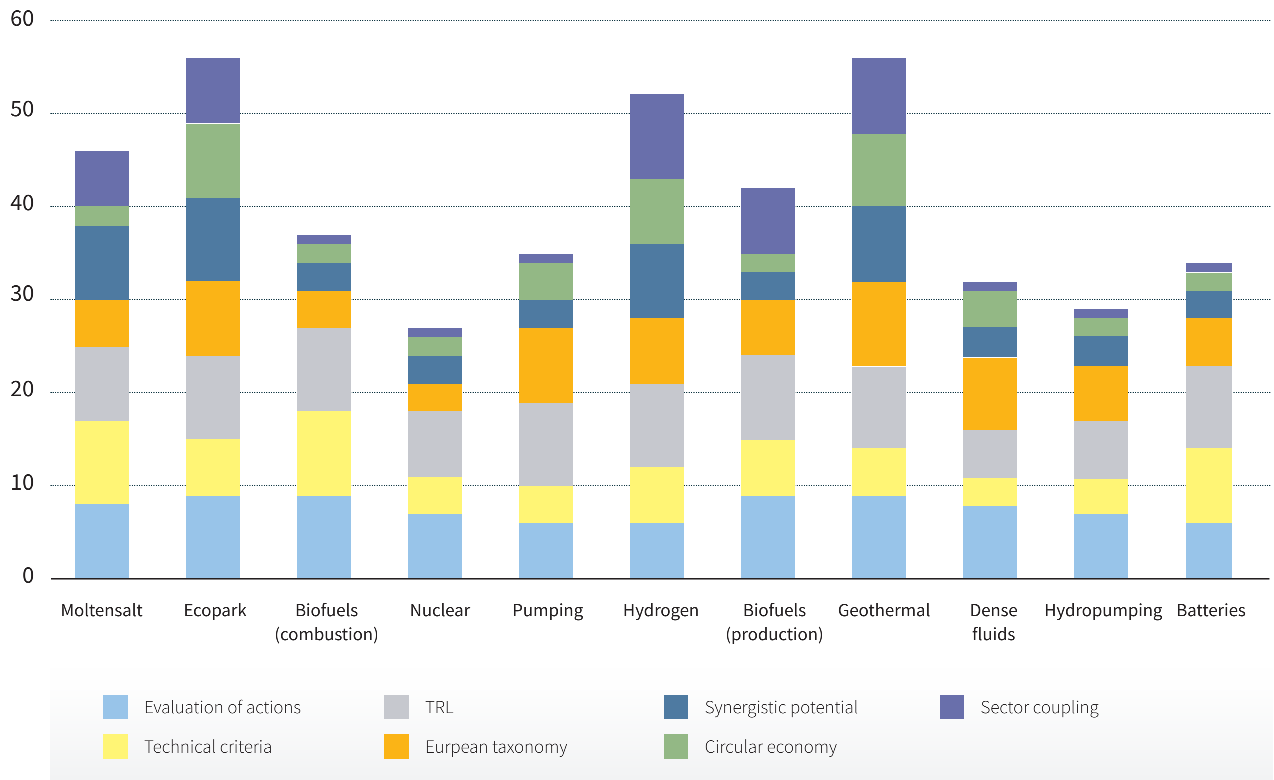


Fig. 4.1 Scenario choice scoring

Addressing micro-actions, Geothermal energy should always be considered when technically and economically feasible in future development scenarios, together with batteries, as they have the second higher TRL from the analysed storage technologies.

Relating energy storage via pumping, dense fluids hydro pumping is better positioned than hydro pumping storage, with the same mean but a more significant standard deviation. Nevertheless, as both technologies are still in intermediate TRLs and the technical requisites for both are sensibly different, starting with the flooding situation of the pit, their selection will depend more upon the specific site characteristics than any other thing.

Lessons learnt within this task were that eco-industrial parks (with virtual power plant) are the most appropriate and exciting business model choice for the considered areas, as they have the second mean in the evaluation of actions, high TRLs of the technologies involved (photovoltaic/wind and geothermal), no problematic requirements regarding the European taxonomy, an exciting contribution to the circular economy and a high level of sector coupling. They may be complemented with a green hydrogen plant and even with a molten salt plant to undergo energy storage.

Eco-industrial parks for the POTENTIALS project can be defined as:

Eco-industrial parks (with virtual power plant) as an integrated alternative to be developed within coupled end-of-life coal mine sites and coal-fired power plants along with surrounding residential/industrial areas for sustainable renewable energy generation (geothermal and photovoltaic/wind), storage technologies, circular economy contributions and synergies for reducing waste and pollution by promoting short-distance transport and optimising the park's material, resource, and energy flows, producing the goods needed for the industrial transition in Europe and cooperating to its achievement.

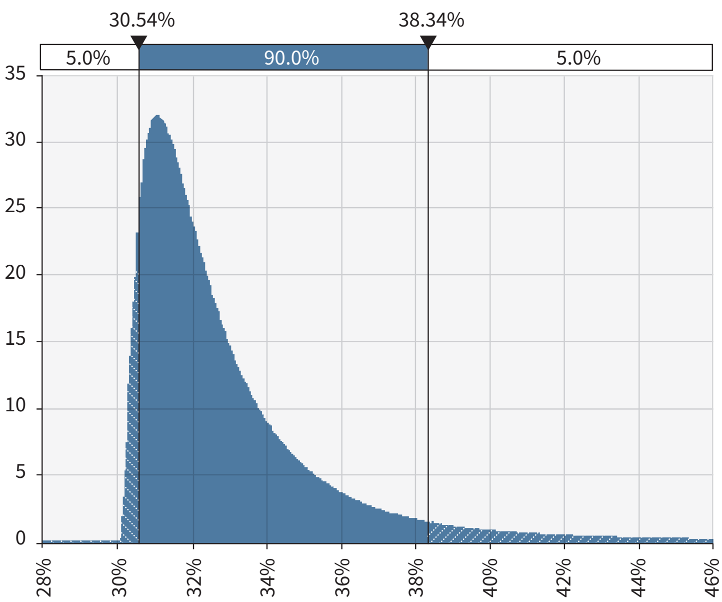
Eco-industrial parks should be based on district networks that allow multiple energy sources to be connected to various energy consumption points, helping to increase photovoltaic deployment by transforming heat and power energy customers into prosumers or customers with excess electricity from solar panels on their roofs. Eco-industrial Parks should be supported by pursuing financial privileges and other benefits to boost and diversify the area's economy, attracting external investment: tax exemptions for industries, access to preferential credits from National authorities, European Investment Bank, etc.

Business models choice justification

4.2. Assessing the economic, social, and territorial impact

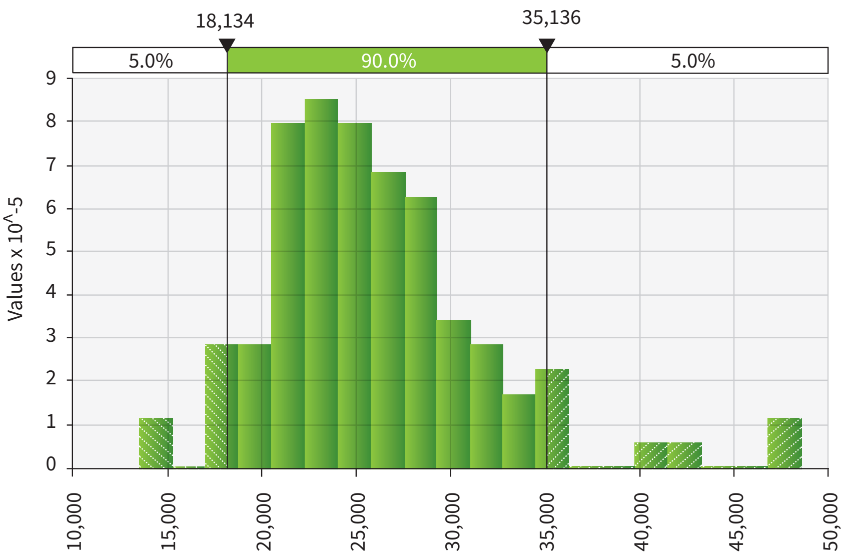
Impact assessments of the before-selected business models, all of them based on Eco-industrial parks with a virtual power plant, were developed: an **economic impact assessment** to determine the economic diversification potential, the likely commercial viability, and the added value of the proposed business models (Fig. 4.2 and Fig. 4.3); a **social impact assessment** analysing the expected job losses and requalification needs; and a **territorial impact assessment** to analyse the potential territorial impact of the business model proposals.

The essential aim of these assessments has been to support the update and re-adoption of territorial just transition plans to avoid inflicting a substantial economic upheaval in the coal regions in transition, limiting the risk of causing an unbalanced territorial or spatial distribution of costs and benefits for different regions.



	Lognorm (0.03,0.03,RiskShift (0.3))
Cell	Sheet1!B6
Minimum	30.000%
Maximum	+∞
Mean	33.000%
Mode	31.061%
Median	32.121%
Std Dev	3.000%
Skewness	4.0000
Kurtosis	41.0000
Left X	30.54%
Left P	5.0%
Right X	38.34%
Right P	95.0%
Dif. X	7.804%
Dif. P	90.0%
1%	30.306%
5%	30.539%
10%	30.730%

Fig. 4.2 *Lognormal distribution of the capacity factor*



	Net Present Value (NPV) / 0
Minimum	13,458.62
Maximum	48,602.32
Mean	26,041.76
Std Dev	5,934.26
Values	100

Fig. 4.3 *Net present value (NPV) distribution*

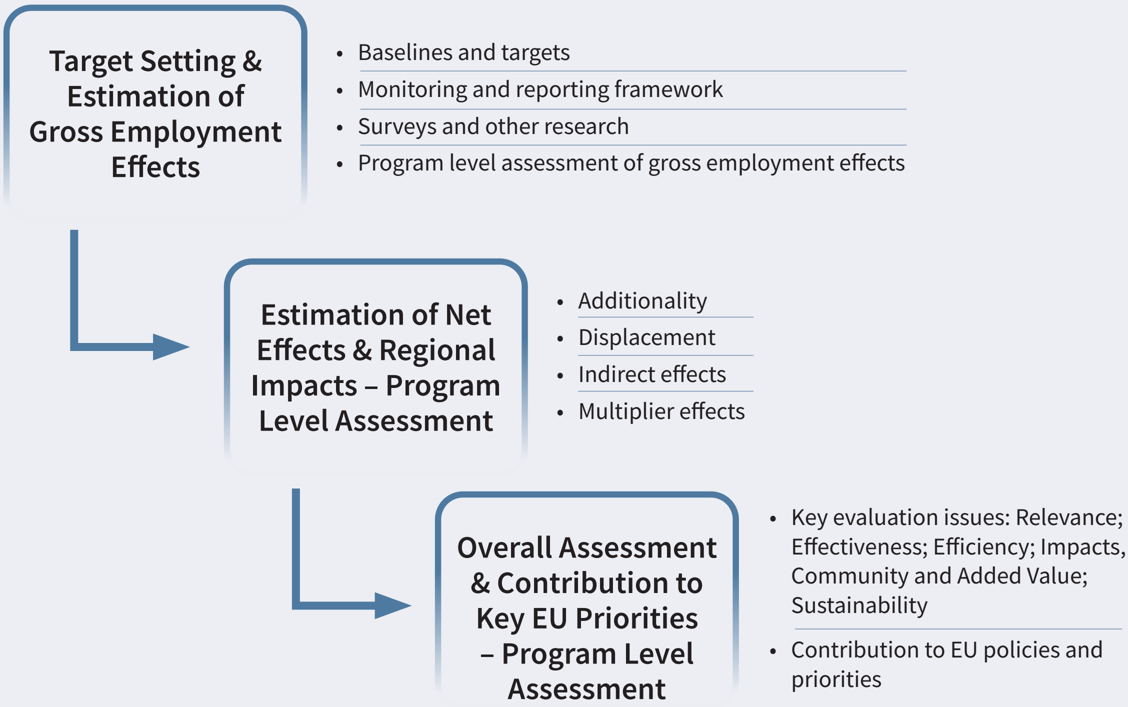


Fig. 4.4 Methodology in evaluating Structural Funds for Employment Effects

The lessons relevant to POTENTIALS from the economic impact assessment can be summarised as follows:
The financial outcomes of the virtual power plant are good, with an IRR of 16%, and the sensitivity and uncertainty analysis demonstrate that the estimated figures are robust. The financial outcomes of the geothermal energy deployment are also positive. However, the IRR reduces to 13%. The financial outcomes for a green hydrogen plant are adverse, and the investment is only feasible if a specific subvention is obtained for its development. A 50% subvention aligning with Big Ticket projects within the Research Fund for Coal and Steel (RFCS) changes the green hydrogen plant into a desirable investment. The financial outcomes from the molten salt plant align with the geothermal energy deployment, although obtaining accurate economic data for this type of installation is extremely difficult.

The lessons relevant to POTENTIALS from the social impact assessment can be summarised as follows:
It is estimated that a total of 160,000 coal-related jobs are expected to be lost by 2030 due to the closure of coal mines and coal power plants. Poland, Germany, Spain and Greece are some of the countries in Europe with a high number of direct jobs in the coal sector and, thus, among the most vulnerable countries in Europe addressing job losses in the coal sector. For the effective employment of eco-industrial park scenarios, it is crucial to consider the option of reskilling employees previously occupied in the coal mining and energy production sector. The necessary skills include general qualifications both coal miners and renewable energy sources workers should acquire that can be modified or used as leverage for effective workforce reskilling. The construction, manufacturing and energy sectors are considered the most suitable for replacing mining jobs, as the salaries offered are similar to those in the mining industry, and there is no need to develop additional skills.

The lessons relevant to POTENTIALS from the territorial impact assessment can be summarised as follows:
A modified Territorial Efficiency, Quality and Identity Layer Assessment (TEQUILA) approach was highlighted as the most suitable to address the challenges and solutions for territorial impact assessment related to comprehensiveness, participatory approaches, data challenges and time perspectives within POTENTIALS (Fig. 4.4). An extensive list of 17 "direct

result indicators" for the relevant scenario outputs developed by the experts of the POTENTIALS project have been condensed to the measurable sub-criteria of the TEQUILA approach and affiliated sub-weights by expert judgements. The positive territorial impact and, therefore, the contribution to territorial cohesion is considerably higher in an Eco-industrial Park with a Green H2 plant, with a total value score of 3.42 than in an Eco-industrial Park with Biofuels production, with a total value score of 2.85. The difference of 0,39 score points in this TEQUILA model comprises varying differences between the three dimensions, which can be shown by direct comparison in each macro-criteria.

Economic, social, and territorial impact assessment

4.3. Business model result indicators

Business model result indicators for the most suitable and exciting business model choice, Eco-industrial parks (with virtual power plant), were estimated. As Eco-industrial parks (with virtual power plants) may be complemented with green hydrogen plants, molten salt plants, batteries and biofuel production or combustion, all these options were considered in the analysis.

The direct result indicators were selected considering the targets set by the European Green Deal and related taxonomy and the Regional Policy indicators for the Just Transition Fund, resulting in a total of 17 direct result indicators whose impact was evaluated through a Delphi experts survey (Fig. 4.5 and Fig. 4.6).

The developed methodology is essential for assessing the potential of specific decommissioned mining plants or power plants. Each of the parameters of the analysed system is of significant importance and may influence the final results of the study and, above all, the selection of the most optimal technology.

Full-Time Employment increase	Green H_2 plant	Molten salt plant	Batteries	Biofuels (production)	Biofuels (combustion)
GIG-TGPE	4	5	1	5	4
HUNOSA	3	3	1	5	4
VGB-THGA	3	3	2	4	4
UNIOVI	5	2	2	4	3
CERTH	4	4	2	4	2
Average	**3,8**	**3,4**	**1,6**	**4,4**	**3,4**

Fig. 4.5 Result of scenarios output for indicator "Full Time Employment creation" after the first Delphi survey

Full-Time Employment increase

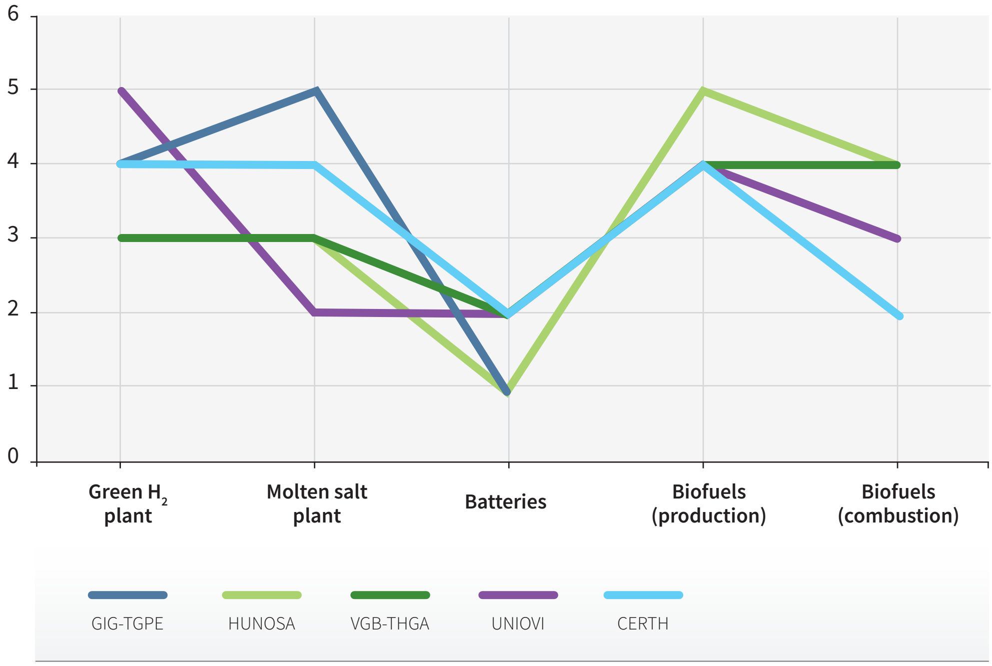


Fig. 4.6 Graph of result of scenarios output for indicator "Full Time Employment creation" after the first Delphi survey

Lessons learnt within this task were that the final scores obtained for the direct result indicators showed an advantage for the scenario involving an eco-industrial park (with a virtual power plant) and a green hydrogen plant. The other scenarios received similar scores and should be considered a complementary range of solutions for further analysis. While considering a portfolio of solutions (business models), and although the results obtained are different for individual technologies, none of them should be rejected. The site-specific requirements may differ due to the "weighting" of technology for individual locations.

The targets set by the European Green Deal and related taxonomy and the Regional Policy indicators for the Just Transition Fund were considered to select the scenario outputs and result indicators, together with the eleven thematic objectives defined according to European Union (EU) Regulations 1300/2013, 1301/2013 and 1303/2013. Also, the study "Development of a system of common indicators for European Regional Development Fund and Cohesion Fund interventions after 2020" (https://ec.europa.eu/regional_policy/en/information/publications/studies/2018/development-of-a-system-of-common-indicators-for-european-regional-development-fund-and-cohesion-fund-interventions-after-2020-part-i-thematic-objective-1-3-4-5-6), which was also focused on the eleven thematic objectives, was of immense help in achieving the goals of this task.

Business model results indicators

5 Roadmap for updating territorial just transition plans

This task presents roadmaps for updating territorial just transition plans, recognising the importance of keeping these plans up to date in alignment with National Energy and Climate Plans and the mid-term review of programs supported by the Just Transition Fund, which offers in 2025 an opportunity for resource reallocation and funding allocation for 2026 and 2027.

They overview the Spanish Just Transition Territorial Plan, focusing on the Asturias region in Spain and the Silesian Just Transition Territorial Plan in Poland. These plans outline strategic frameworks, transition strategies, and operational activities to achieve a sustainable and equitable transition in their regions. Regular updates to these plans are crucial to address evolving challenges and maintain their effectiveness in guiding the Just transition process.

A possible and feasible update is presented for each region, trying to complement or correct the different operations envisaged to propose initiatives that stimulate the regional economy, making it easier to maintain employment.

In the case of Asturias, the territorial just transition plan aims to mobilise investments to stimulate and reactivate the regional economy and create quality employment to fix the population.

Three are the planned concentrating activities to achieve this goal: First, the renewable hydrogen value chain; Second, the renewable energy value chain complemented with energy storage; and Third, an economic transformation towards a more sustainable, digital, and environmentally green industry (Fig. 5.1)..

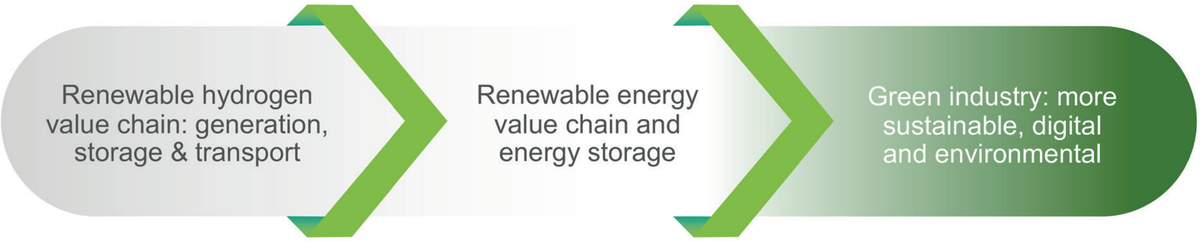


Fig.5.1 *Asturian Just Transition Plan initiatives with reference projects*

Two are the operations envisaged by this Just Transition Plan: to promote individual projects within the previous initiatives, and to create innovation poles and centres using existing infrastructures, focusing on Artificial Intelligence, Agri-food industry, Data storage, valorisation and cybersecurity, and, finally, Industrial innovation (Fig. 5.2).

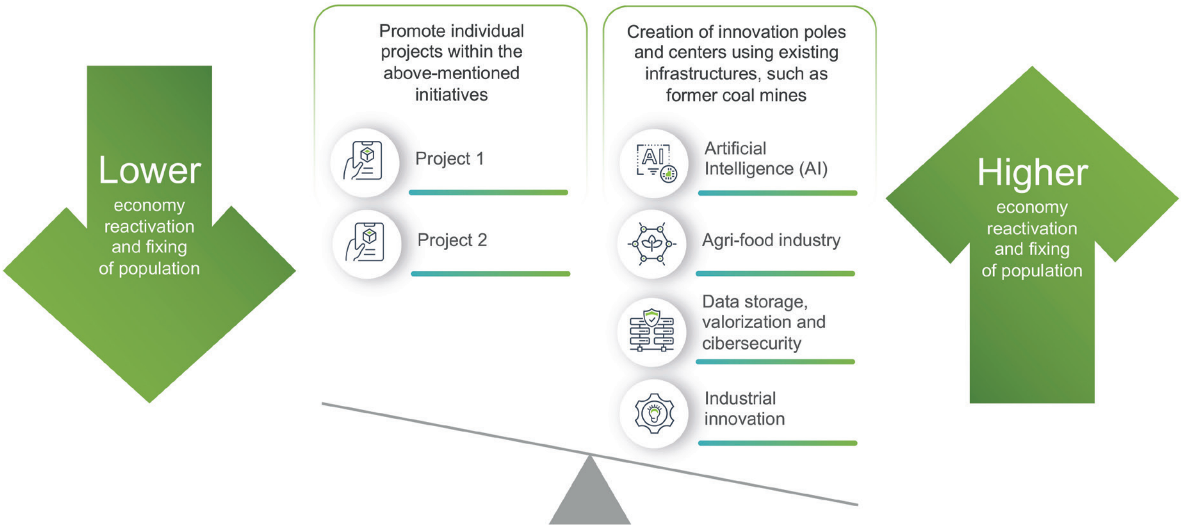


Fig.5.2 *Operations envisaged by the Just Transition Plan*

However, Asturias Just Transition Plan fails to propose an initiative to stimulate the regional economy, making it easier to maintain employment: Eco-industrial parks with Virtual Power Plants (Fig. 5.3).

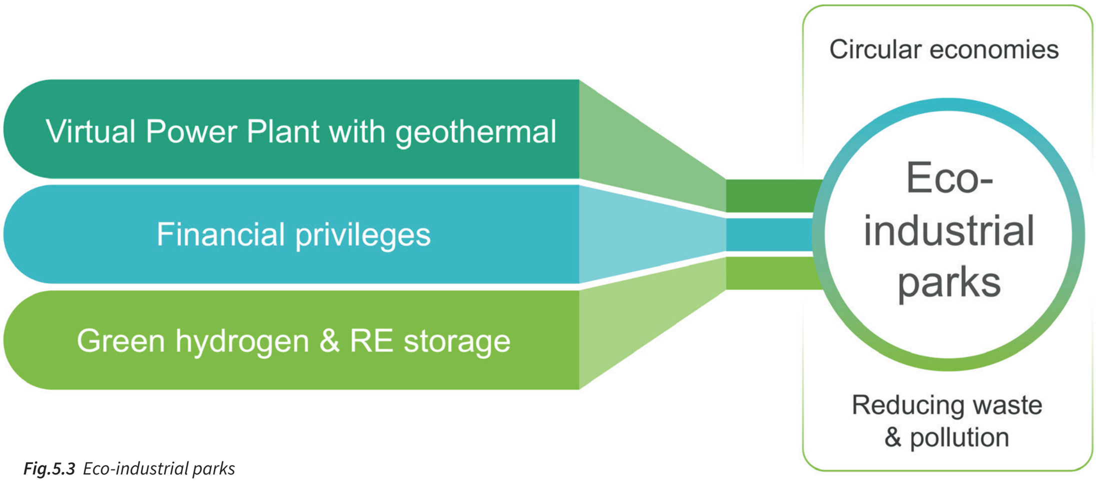


Fig.5.3 *Eco-industrial parks*

In the case of Silesia, the proposition for utilising the POTENTIALS project's achievements in the territorial just transition plan update includes the development of an Action Plan that will incorporate prioritising business models concerning operational goals.

The prioritisation of business models was conducted using the widely adopted MoSCoW technique. This technique enables the analysis of priorities and focuses on critical elements crucial for the successful implementation and transformation. As a result, the Action Plan provided clear guidelines on which business models should be prioritised during the update of activities within the territorial just transition plan, along with accompanying actions (e.g., competency framework development and spatial planning), and allocated the budget accordingly (Fig. 5.4).

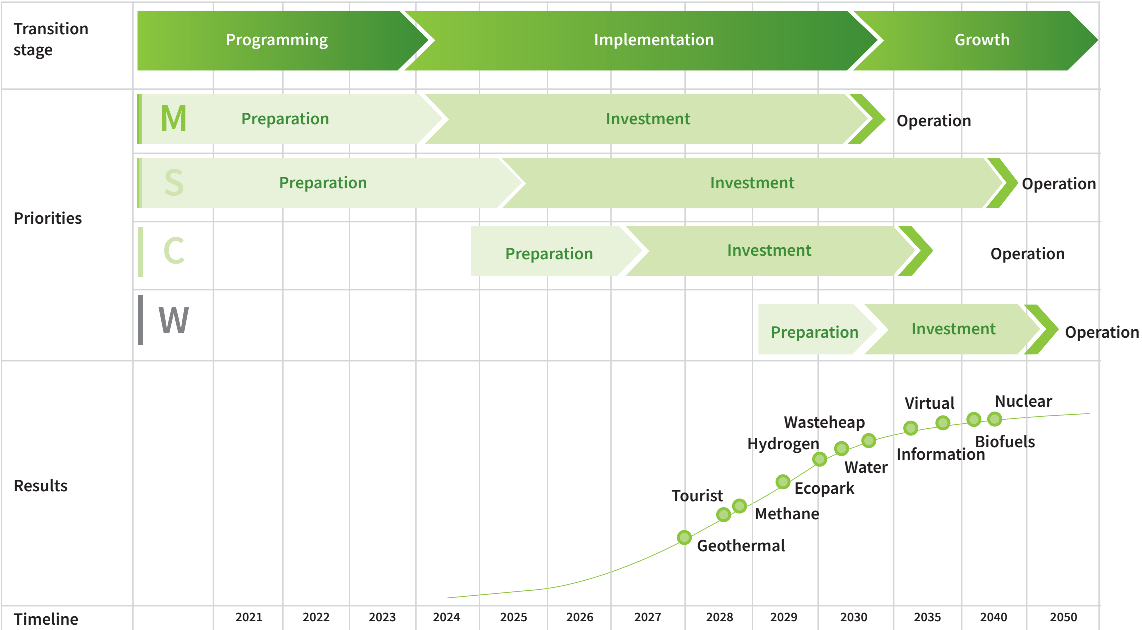


Fig.5.4 Road map for update of Just Transition Plan for the Silesian region

Lessons learnt within this task were that promoting individual projects within planned concentrating activities has a negligible effect on economic reactivation and population fixing. Innovation poles contribute more to economic reactivation and population fixing than individual projects due to the synergies they can achieve. However, they are challenging to implement due to their specificity.

The initiative that can genuinely stimulate the regional economy, making it easier to maintain employment, is Eco-industrial parks with Virtual Power Plants, an integrated alternative for sustainable renewable energy generation, storage technologies, energy vectors, circular economy contributions, and synergies for reducing waste and pollution. They have as a counterpart the need to be supported with financial privileges and other benefits to boost and diversify the area's economy and employment, attracting external investment. However, is that not the aim of the Just Transition Fund?

Finally, when developing a roadmap for updating territorial just transition plans, it is necessary to determine the future approach to emerging areas after phasing out mining and power plant activities. If these areas are to be developed according to business models, pre-investment preparations should be carried out. Specifically, a feasibility study and preliminary implementation plan should be developed for each business model.

Roadmap for updating territorial just transition plans

6 Conclusion/Outlook

The prioritisation of business models concerning the goals of a territorial just transition plan indicates that the most desirable models during the plan's update phase will be those aiming to establish or transform existing eco-industrial parks in the region.

These parks can provide a flexible framework for achieving the territorial just transition plan's goals, focusing on sustainable energy sources and socio-economic objectives, essential pillars of the just transition process. Combining sustainable energy generation technologies with energy storage in a single business model, integrated with economic activities and projects, presents a unique opportunity for employment growth and innovation in the region.

Additionally, the utilisation of post-mining areas and former power plants for tourism and/or recreational activities, coupled with the production of green energy, has been included. Such solutions have been successfully implemented in different countries. However, often, without the integration of energy production, these areas are not self-sustaining and challenging to maintain. Introducing sustainable energy-related solutions can lead to increased interest and better utilisation of such areas, not only for tourism purposes but also for economic development.

The energy transformation of regions requires the provision of new energy production and storage sources. One of the recommended solutions in feasibility studies is introducing a green hydrogen plant where renewable hydrogen will be produced through electrolysis of mine water and electricity from renewable sources. The potential of the areas and the existing infrastructure favour such a solution, which would achieve employment and economic revitalisation goals and promote environmentally friendly mobility and new R&D directions.

An outlook of the process of updating a territorial just transition plan can follow this phased structure:

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1. **Analysis and evaluation of the existing plan:** The first step is thoroughly evaluating the existing territorial transition plan. In this stage, it is essential to understand what goals have already been established, what actions have been taken, and what financial resources have been allocated.

2. **Consultation and stakeholder engagement, including society:** The next important step is to engage various social groups and stakeholders in updating the plan. Organising consultations, meetings, discussions, presenting potential solutions (e.g., business models), and gathering feedback are crucial to incorporating different perspectives and community needs.

3. **Needs and priorities analysis:** A detailed analysis of needs and priorities should be conducted based on consultations and community input. This stage can consider social, ecological, economic, and technological factors to determine areas that require more significant support.

4. **Updating goals:** Goals should be updated based on the analysis of needs and priorities. Goals should be measurable, achievable, and aligned with the values of the community.

5. **Updating actions and financial resources:** After establishing new goals and strategies, specific actions should be defined, incorporating proposed business models for implementation within the plan. Actions should be well-defined, evidence-based, and consider the needs of different social groups. It is also essential to anticipate the availability of these actions' financial resources and funding sources.

6. **Planning for monitoring and evaluation:** An essential element of the plan updating process is to plan a system for monitoring and evaluating the progress of actions. This includes determining indicators, monitoring methods, and regular progress reviews to ensure that goals are achieved, and actions are adjusted as needed.

7. **Adoption and implementation of the plan:** After updating, relevant authorities or organisations should adopt the territorial transition plan. Implementation of the plan can begin.

It is essential to consider diverse business models based on sustainable development principles, eco-innovation, circular economy models, or clean technology-based models. Collaboration and dialogue among stakeholders, including entrepreneurs, government institutions, and civil society organisations, are crucial to ensure that business models are well integrated in the update of the Just Transition plan.

By way of an epilogue

EURACOAL organised a workshop on the EU Research Fund for Coal and Steel (RFCS) transformational projects for a new era on May 23, 2023, to promote the RFCS. MEP Ondřej Knotek kindly hosted the workshop in the European Parliament.

Brian Ricketts, Secretary-General of EURACOAL, led the first part of the workshop. Mr. Marc Lemaître, Director-General for Research and Innovation, addressed participants with a well-crafted video message. Having overseen the European Regional Development Fund and Cohesion Fund, as well as the Just Transition Fund, which is important to the coal regions, he was keen to see research funds used to support a just transition that left no one behind.

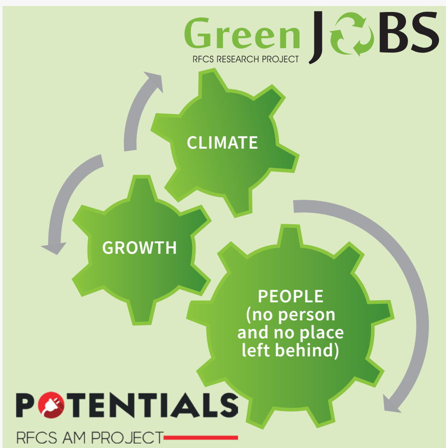
EURACOAL President Tomasz Rogala thanked MEP Knotek for hosting and the European Commission's efforts to modernise the RFCS research program. He welcomed the larger budget, especially the support offered under big-ticket calls, which will help coal regions through the energy transition. Dr Rogala, Chairman of the Board at the Polish Mining Group (PGG – Polska Grupa Górnicza), explained the plans for transition in his country, which depends on coal for 70% of electricity generation.

From the European Research Executive Agency (REA), Dr Sebastiano Fumero, Head of Unit – Future Low Emission Industries, explained the new RFCS objectives and calls worth €111 million each year, which can support transition projects in the coal regions as part of the European Green Deal. Looking ahead, he reiterated the need for more, high-quality proposals from the industry that can make a substantive impact in line with EU policies. Given the much larger funding available, he was optimistic about the RFCS's role in a just transition.

The second part of the workshop was led by Prof. Alicja Krzemień, Chair of the EURACOAL Technical Research Committee and Head of the Laboratory for Risk Assessment and Industrial Safety at the Central Mining Institute – National Research Institute (GIG-PIB) from Poland. She highlighted two RFCS-funded projects concerned with a just transition: POTENTIALS and GreenJOBS, which show how accompanying measures and research projects can support green business development models for the coal regions – especially in the energy sector.

A series of short presentations on lessons learned from the two projects were introduced, firstly on regional transition under the EU-funded Territorial Just Transition Plans in the different coal regions of Spain, Greece, and Germany, followed by feedback from industry on such plans in Slovenia, Spain, Germany, the Czech Republic, and Poland.

EU Research Fund for Coal & Steel
transformational projects
for a new era



Mr. Marc Lemaître. Director-Generall for 'Research and innovation". European Commission.

Starting from the left: Dr. Sebastiano Fumero, Head of Unit REA.B1 – Future Low Emission Industries, European Research Executive Agency (REA); MEP Ondřej Knotek, Renew Europe Group; Dr. Tomasz Rogala, President of EURACOAL and Chairman of the Board, Polska Grupa Górnicza S.A. (PGG – Polish Mining Group).

POTENTIALS

RFCS AM PROJECT

PARTNERS IN THE PROJECT

Central Mining Institute National Research Intitute Poland	**VGBE Energy Is Us** Germany	**Universidad de Oviedo** Spain
CERTH Centre for Research & Technology Greece	**Hulleras del Norte S.A.** Spain	**Technische Hochschule Georg Agricola** Germany